JOURNAL OF THE PALAEONTOLOGICAL SOCIETY OF INDIA
VOL. 16, 1971, pp. 1 — 15

# STRATIGRAPHY AND SEDIMENTATION OF TAL FORMATION MUSSOORIE SYNCLINE, UTTAR PRADESH*

RAVI SHANKER

Geological Survey of India, Lucknow

ABSTRACT—Tal Formation of the Mussoorie Syncline, in parts of Dehradun and Tehri districts, Uttar Pradesh, has been studied and the stratigraphic succession established:

| | |
|---|---|
| Subathu Formation | |
| | Unconformity |
| Upper Tal Formation | ———— (ii) Limestone member————— |
| | (i) Quartzite member |
| | ———— Disconformity————————— |
| Lower Tal Formation | (iv) Calcareous member |
| | (iii) Arenaceous member |
| | (ii) Argillaceous member |
| | (i) Chert member. |
| | ———— Disconformity (?) /Sub-marine/Transitional at places/diastem |
| Krol Formation | |

Attempt has been made to decipher the conditions of deposition of the significant litho-units associated with the recently demarcated phosphate deposit.

The history of Tal sedimentation indicates cycles of deposition by alternate marine transgression and regression of a shallow sea over gently sloping and slightly undulating basin topography. The restricted circulation, the relatively shallow depth of water, and the uneven basin floor topography appear to be the main controlling factors in the formation of phosphate rock.

The original basin, in which the Tal sedimentation commenced, extended much beyond the present limits of the Mussoorie syncline.

*Published by the kind permission of the Director General, Geological Survey of India.

## INTRODUCTION

Recent emphasis on the exploration for the rock phosphate necessitated the re-examination of the Tal Formation in parts of Uttar Pradesh and Himachal Pradesh. With a view to unravelling the stratigraphic complexities of the Tal Formation and to demarcate the phosphate bearing zones for detailed exploration, remapping was done on scale 1:31,680 and also on 1:1000 scale of selected areas in parts of Mussoorie Syncline in Dehradun and Tehri districts of U.P.

## STRATIGRAPHY

Distinctive lithology and its mappability sharpness and easy recognition of the surface of contacts warrant a two-fold classification of the Tal rocks, i.e., Lower Tal Formation and Upper Tal Formation*. Incidentally the surface of contact between these formations also represents a break in sedimentation in parts of the area and sharp change in the environment of deposition. Thus, the boundary between the Lower and Upper Tal Formations is both natural and distinct. Stratigraphic and tectonic sequence established by the author is given in the Table 1.

TABLE–1

| | | | |
|---|---|---|---|
| Garhwal Thrust Unit | Schistose phyllites<br>Limestone and quartzite<br>Volcanic tuff | | Older Palaeozoic |
| ——— Garhwal Thrust ——— | | | |
| Subathu Formation | Olive shale, Shell marl and Limestone | | Lower to Middle Eocene |
| ——— Unconformity ——— | | | |
| Upper Tal Formation | (ii) Limestone member (Shelly Calcareous) Grits. | 15-20 m. | Lower and/or Middle Cretaceous |
| | (i) Quartzite member (Sequence of quartzite arkoses, grits to pebbly quartzite and thin grey, to green shales, red siltstones often mud cracked) | | |
| ——— Disconformity ——— | | | |
| Lower Tal Formation | *(iv)* Calcareous member Ferrugineous, siliceous or sandy limestone | 5 m. | |

* Based on lithologic character and their mappability each sub-division is a rock-stratigraphic unit, with its boundary not necessarily following a time plane and, therefore, the terms 'formation' and 'member' are preferred to 'series' and 'stage' etc. as used for Krol and Tal by all the previous workers.

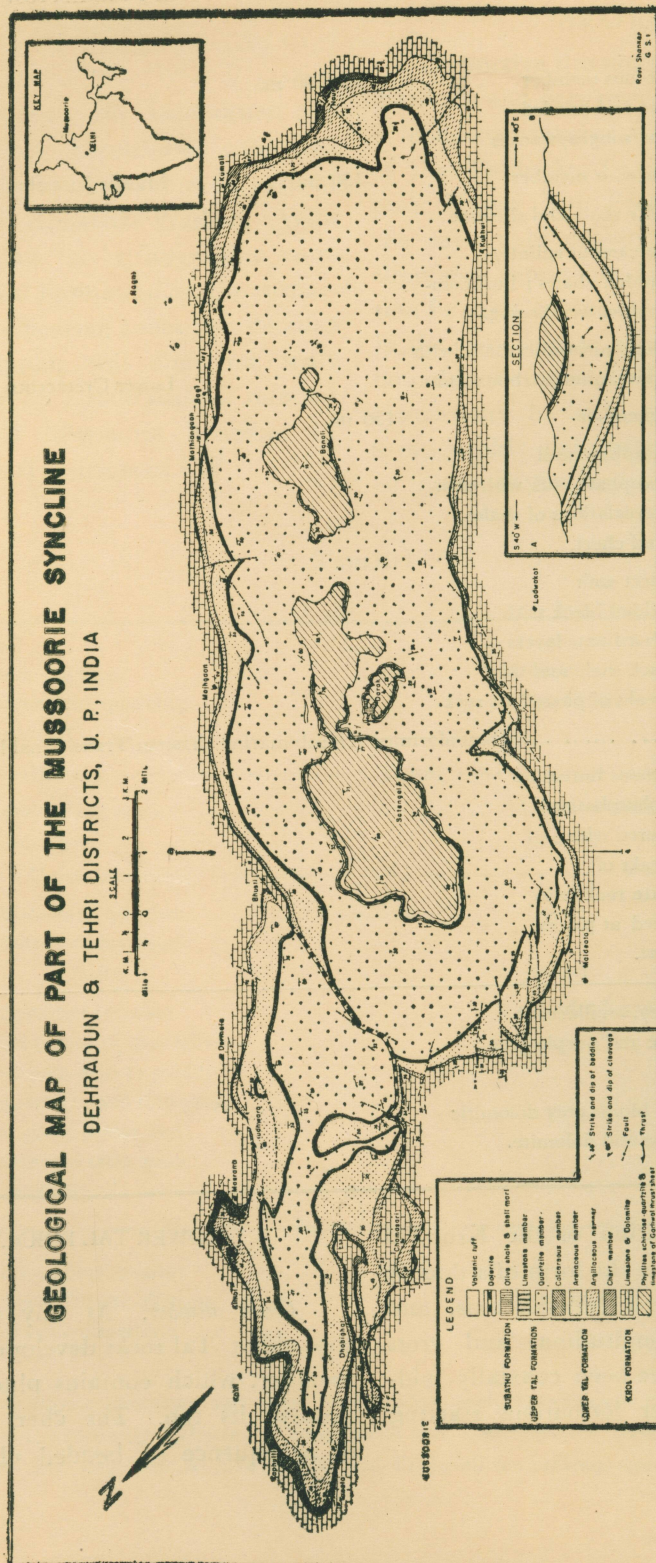
*Contd. from Page 2* .....

| | | | |
|---|---|---|---|
| | *(iii)* Arenaceous member Massive and banded siltstone/subgraywackes | 300-500 m. | |
| | *(ii)* Argillaceous member | 150 m. | Middle Jurassic |
| | (c) Silty shale and siltstone | | |
| | (b) Calcareous splintery, banded shales ; buff coloured on weathering. | | to |
| | (a) Black micaceous shale, with pyrite, often carbonaceous | | Lower Cretaceous |
| | *(i)* Chert member | 150 m. | |
| | (b) Phosphate unit Phosphate rock with thin intercalations of shales and chert. | | |
| | (a) Chert unit Bedded black with subordinate layers of black shale and thin streaks of phosphate rock. | | |
| ........................................ Disconformity (?)/Sub-marine diastem/Transitional locally. | | | |
| Transition zone (developed locally) | Argillaceous limestone (often phosphatised) interlayered with thin streaks of phosphate rock (also brecciated at places) and chert. | | |
| Upper Krol Formation | *(ii)* Light grey, argillaceous limestone and purple grey shale | | |
| | *(i)* Grey to bluish grey dolomitic limestone and dolomite. | | |

The present disposition of the Krol-Tal rocks in the area is in the form of a doubly plunging syncline with a NW-SE axis, and traversed by both longitudinal and cross faults. These rocks have been coaxially folded along with those older formations starting from the Chandpurs.

## LOWER TAL FORMATION

*Chert member.* At any particular place the oldest Tal rocks developed belong to this member, which contains phosphatic deposits towards its top. The chert member consist of a sequence of bedded chert, chert-shale


GEOLOGICAL MAP OF PART OF THE MUSSOORIE SYNCLINE
DEHRADUN & TEHRI DISTRICTS, U. P., INDIA
SCALE
KEY MAP
DELHI
Mussoorie
SECTION
LEGEND
Volcanic tuff
Dolerite
SUBATHU FORMATION
Olive shale & shell marl
UPPER TAL FORMATION
Limestone member
Quartzite member
Calcareous member
Arenaceous member
LOWER TAL FORMATION
Argillaceous member
Chert member
KROL FORMATION
Limestone & Dolomite
Strike and dip of bedding
Strike and dip of cleavage
Fault
Thrust
Satengal
Bangli
Kumalti
Mathiagaon
Ladwakot
Maldeota
MUSSOORIE
N

Text Fig. 1

alternations and phosphate rock with thin alternations of black shale. The boundaries of this member are fairly well defined. It overlies the argillaceous limestone or dolomitic limestone of the Krol Formation. Occasionally a thin transition zone of limestone-phosphate rock/or chert alternations has also been encountered. The top is marked by the last occurrence of phosphate rock or chert. The black chert is often thickly bedded and is generally nodular towards its upper portion but below the main phosphatic zone. These nodules range in diameter upto two or three centimetres and are usually highly phosphatic whereas the cherty matrix in which they are embedded is generally non-phosphatic or only mildly so. Tiny phosphatic nodules also occur in the shaly intercalations. Thin bands of black carbonaceous algal limetsone are also sometimes found in the chert member. Pyrite is occasionally associated in the rocks of the chert member Chert unit is best developed in the north-western part of the syncline (Toneta-Kaphulti), where it attains a thickness of about 150 metres. The thickness, however, decreases southeastwards. Southeast of Durmale, on the northern limb and east of the Bandal river on the southern limb, the chert unit is not developed and the chert member is represented by the phosphate unit only.

Phosphate unit generally consists of phosphate rock (rock composed essentially of phosphatic minerals) with or without chert and/or shale intercalation. Phosphate rock in this area is generally dull grey to brownish black in colour, nodular, granular to massive aphanitic in texture, occasionally bedded, brittle and friable; on weathering white, orange, yellow, bluish encrustrations are seen, at times on the surface. Higher radioactivity upto 10 times the background count or more has often been noticed in the phosphatic zones. Megascopically four distinct varieties of phosphate rock could be recognised.

(a) *Friable platy and laminated variety:* These are thinly bedded, dark grey to dark greyish black in colour, commonly friable in nature, sometimes weathering with a brownish tinge. This is the most common variety of the higher grade phosphate rock met with in this area.

(b) *Granular variety.* Associated with the phosphate rocks discussed above are thin bands of dark to light grey phosphate rock having a distinct granular texture.

(c) *Variegated lenticular and pelletal variety.* This is greyish white to medium dark grey in colour and consists of pellets and lenticles of dark coloured phosphatic materials embedded in a less phosphatic calcareous or cherty matrix. This variety is locally seen at the lower part of the sequence and is generally low to medium grade in $P_2O_5$ content.

(d) *Nodular variety.* This variety consists of greyish to dark greyish and black coloured small nodules of varying sizes set in a light grey coloured calcareous matrix. This variety also generally does not exceed 15% in $P_2O_5$ content and is locally represented in the lowermost part of the Lower Tal Formation.

Mineralogically the phosphatic materials consist mostly of isotropic collophane (carbonate hydroxyl flourapatite), with some fibrous anisotropic francolite and dahllite.

Phosphate unit varies in thickness from streaks to about 18 metres. However, the zones over 5 metres in thickness are found only in Kimoi-Masrana, Maldeota, Durmala and Jalikhal areas. The area between Kimoi-Masrana and Paritibba-Castle hill represents the zone of interfingering of phosphate and chert units, therefore, there are more than one phosphatic bands in the phosphate unit.

As the upper bounding surface of the chert member marks the transition from chemical or non-clastic to clastic sedimentation in the basin, it could be regarded as an approximate or closely approaching time surface.

*Tuffaceous rock.* Occurrence of a light grey to grey coloured, hard and porous rock, just overlying the phosphate unit deserves special attention. This occurs as a discontinuous band varying in thickness from 20 cm to about one metre in Paritibba, (Ghose 1968).

Under the microscope, this is a fine grained rock containing xenomorphic irregular patches of greenish brown to brownish grey in colour, with low to moderate birefringence and interference colour whlch is mostly masked by body colour, enclosed in a groundmass consisting of extremely fine grained microcrystalline anhedral silica grains possibly with a little felspar. The xenomorphic irregular shaped patches possibly represent shreds and patches of devitrified glass altered to a mixture of chlorite and palagonite (Ghose, 1968).

So far no prolific fauna or flora have been encountered in the chert member except a thin algal limestone in the Chamasari area (Raha 1968); and hystrichosphaeres and tricolpate pollen of angiospermous affinities in the topmost part of the chert member from Maldeota area suggest that the deposition of chert member continued probably till Upper Aptian or possibly Albian (Shrivastava, R.N. & Mehrotra, P.C., 1970).

*Argillaceous member.* This member comprises a sequence of light grey to black shale often carbonaceous, pyritic, micaceous and at times sandy. These shales grade upwards into arenaceous shales, olive to grey splintery shales, and light coloured well cleaved shales with characteristic buff and brown banding. The splintery and cleaved shales are at times calcareous. At times greyish to greyish white argillaceous limestones are seen in them. Splintery and sandy or arenaceous shales often grade into each other laterally. Towards the top portion of this member the shales become silty before grading imperceptibly into the Arenaceous member. Nodules of various shapes and sizes are found in the black shales. The diameter of nodules ranges from 1 mm to as much as 50 cm. The phosphate content of these nodules seems to vary and is by and large inversely proportional to the size; i.e., the smaller the nodule the higher is usually the phosphate content. The maximum thickness of this member is of the order of 150 metres.

Though rich fauna or flora have not been found in this member, some doubtful lammellibranch shells, coral-like bodies and some tubular bodies are found in the back shales of Argillaceous member of the lower Tal Formation. R. N. Srivastava has ecognised a pelecypod—*Posidonia ornati*—a Middle Jurassic form, from the black shales near Surkhet. He has also reported, from similar rocks near Bagi area, some crusacean forms (*Estheris marginata* Defretin) which are similar to those described from the Neocomian beds of Nigeria. (1963 a, b)

*Arenaceous member.* This member consists of a thick succession of grey massive siltstone, dark grey to black, fine grained, well bedded micaceous siltstone (sub-graywacke) showing characteristic brown banding and at times faint current bedding, intercalated with grey silty shale. These brown bands are composed of slightly coarser material than the black ones. The siltstone, at places, shows some cast structures at the lower surfaces. Some worn tubes are also found in the siltstone in the Chipaldi nalla section. At times the brown bands, described above, are highly contorted and folded in an otherwise undisturbed bed (as on Masrana-Laharigarh-Sahastradhara mule track) indicating probably the effects of penecontemporanaeous agitation or shaking of the basin floor. Though graded bedding is not so prominent when viewed megascopically, yet these light (brown) coloured sandy bands sometimes show micro-graded bedding when seen under the microscope.

Banded siltstone gradually becomes quartzitic in the higher horizons till it grades into light grey, fine grained quartzite at the top of the member. The maximum thickness of this member varies between 300 m and 500 m.

Though the superficial megascopic characters and to some extent the textural and structural characters of this suite of rocks in the area bear close resemblance with those of graywackes proper, the mineralogical characters with lesser percentage of felspar and lack of well defined rock fragments indicate an assemblage somewhat resembling in character of sub-graywackes rather than graywackes.

*Calcareous member.* The calcareous member varies in thickness from one to five meters. Though thin, this band of grey to bluish grey, siliceous limestone, which is generally ferruginous, is a very characteristic horizon in the Tals. With the increase in the content of siliceous material the rock attains the characters of calcarenite. This siliceous limestone weathers into diagnostic brownish colour, earthy-looking mass, which seldom fails to attract attention in an otherwise monotonous sequence below and above it.

This limestone is associated with thin layers of fine grained pinkish grey to grey coloured micaceous sandstone and red and grey shales. The associated micaceous sandstone is fine-grained compact and grey to pinkish grey in colour. Being lighter in shade these are distinct from the underlying dark coloured siltstone suite of rocks, the lighter coloured varieties of this unit are sometime speckled and constitute salt and pepper sandstone sometimes with rounded black clayey patches on a grey groundmass. These rocks are well laminated and occasionally cross bedded.

Mineralogical, textural and structural characters and association with shale and arenaceous limestone indicate that these sandstones are typical sub-graywacke.

This member is an excellent marker horizon, because of its small thickness, lateral persistency of characters combined with the easy recognisibility in field. Many a small fault could be recognised in the field by noticing the displacement of this member. The possibility that this member is a good time marker cannot be completely ruled out.

## UPPER TAL FORMATION

It is dominantly a quartzitic sequence with a thin calcareous capping, and therefore, has been divided into a lower quartzite member and an upper limestone member.

*Quartzite member.* Immediately overlying the Calcareous Member of the Lower Tal Formation, is a thick accumulation of medium to coarse grained, white, grey (spotted) to pinkish, micaceous quartzites, often gritty and pebbly and fine-grained soft, green to purple silty sandstone, olive shales and purple clays. In pebbly quartzites, the sub-angular to sub-rounded pebbles of quartz (upto one cm in length) are embedded in gritty quartzose matrix. These are overlain by thick bedded arkosic quartzites, which in turn are succeeded by a zone of medium grained quartzite and bluish algal limestone alternations. This is best developed near the village of Dhaulagiri. The top part of this member consists of white coloured fine grained, quartzite with tiny pyrite specks and few thin beds of feebly calcareous, white sandstone and reddish siltstone. The quartzites of this member are well and thickly bedded. Current bedding is common and some amount of shearing is observed along the current bedded planes.

At the base of this member, a thin band of conglomerate is encountered at a few places. This conglomerate is made up of grey to dark coloured pebbles of siltstones, derived from the Arenaceous member, embedded in gritty and quartzitic matrix. Sometimes the basal beds of this member are formed of grey to greenish grey and purple siltstones, shales, silty sandstones and red clays, which are highly ripple marked (both current and wave ripples) occasionally exhibiting mud cracks and rain drop impressions (?), *e. g.*, near Masrana on Tehri Road and in nearby areas. These beds are at times interbedded with white, coarse arkosic quarzite. The complete sequence of the quartzite member is seen only in the central portion of the syncline. The maximum thickness of this member is about 1300 metres.

*Limestone member.* On the top of the quartzite member is a band of light grey to bluish grey, highly sandy, shell-limestone about 20 m in thickness. On the weathered surface, this limestone, displays, subangular to sub-rounded quartz grains embedded in calcareous matrix. Sometimes the percentage of quartz grains is appreciable when the term calcareous grit could be better suited to the rock. This limestone often exhibits faint current bedding and contains numerous broken shell fragments pelecypods, gastropods, crinoid stems and belemnites etc., which are difficult to identify in the field.

From a study of the collections made from this limestone from an adjoining syncline (Garhwal Syncline), B. S. Tiwari, and

Gupta, 1967 reported the following fauna:—

"Cylostomatan Bryozoa—*Leterocavea* d'Orbigny 1853—of Family Petaloporidae, Gregory, 1899. The genus is confined to the Lower Cretaceous (Aptian). Foraminifera of Family Miliolidae, Rotaliidae and Texulariidae have also been met with. In addition this rock also enclosed fragments of Dasycladaceae algae, probably referable to genus *Neomeris.*"

This member is overlain by the Subathu Formation (Eocene age).

## KROL-TAL CONTACT

Broadly speaking, and on a regional scale, there is no discordance between the Krol limestone/dolomitic limestone and the overlying lowermost beds of the Lower Tal Formation. Stratigraphically the lower Tal rocks are found to rest over different members of the Upper Krol formation at different places representing a disconformity. Sub-aerial erosion of the Krol limestone has not been demonstrated in the Mussoorie Syncline as evidenced by the lack of submerged topography of Krol beneath the chemical precipitates of the chert member. However, the aerial erosion is reported further to the east in the central and eastern part of the Garhwal Syncline (Rupke, 1968). Minor undulations in the surface of contact and occurrence of nodular bed in some of them represents a period of submarine erosion and non deposition. Thus, the disconformity at the base of the Tal Formation may, therefore, be of the nature of submarine diastem in the Mussoorie Syncline. However, occasionally a thin transition zone of limestone-phosphate rock/chert alternations have also been encountered (Masrana, East of Maldeota).

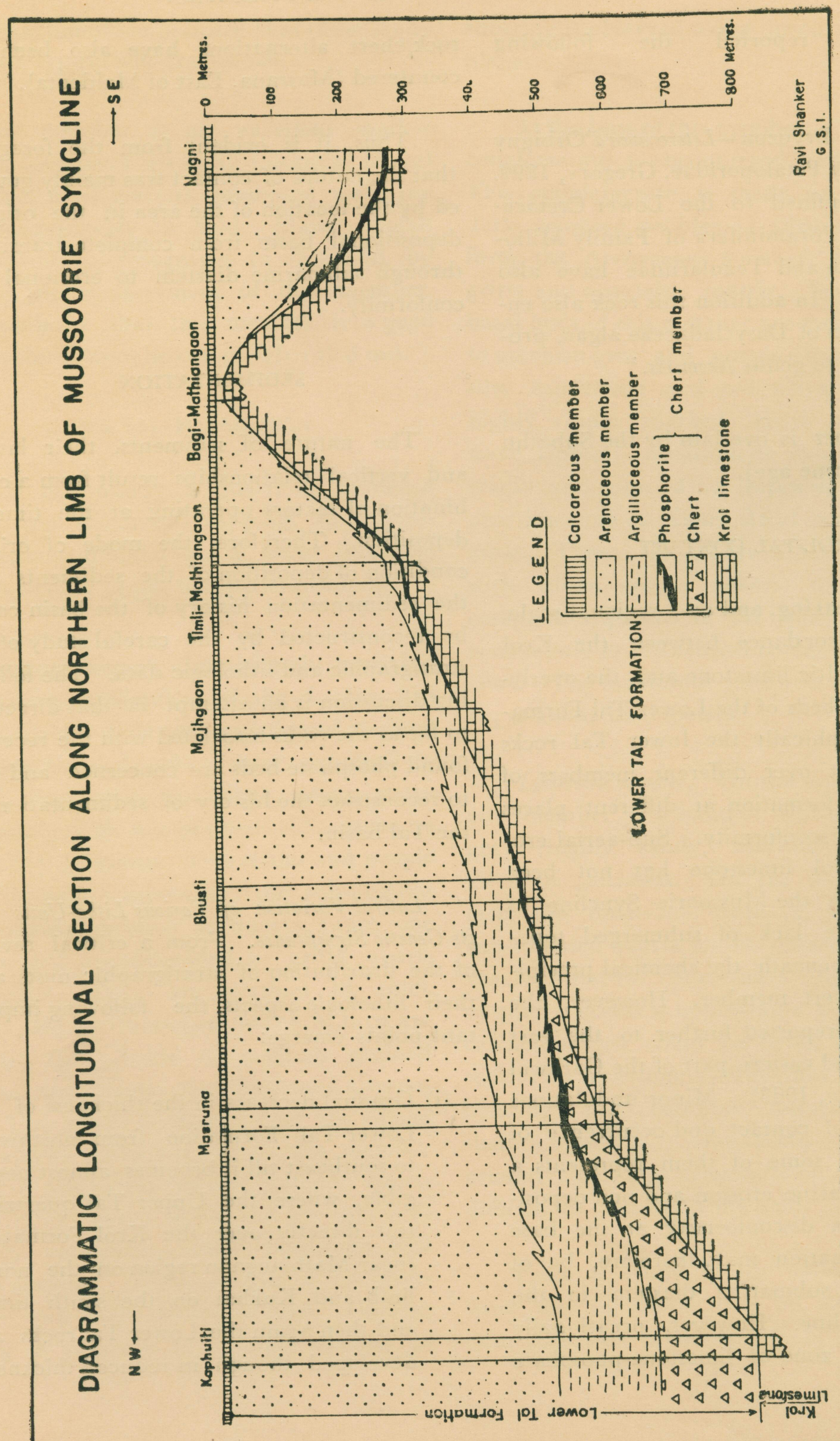
Thus, it is evident from the foregoing that the nature of contact was mainly governed by the location of the area in the original depositional basin from complete transition, through submarine diastem to erosional unconformity.

## SEDIMENTATION

The nature of sediments, their lateral and vertical relationships result from a combination of factors operating at the time of deposition. Therefore, the mode of origin, condition of deposition of the sediments and the sedimentation history of the basin could be reconstructed by the careful study of the stratigraphic and lithologic data. The following discussion is an attempt in that direction so far as the rocks associated with the recently found phosphate beds are concerned and also to reconstruct the history of sedimentation of the Tal basin.

*Lateral Variation of Various Litho-Units and its Genetic Significance.* From a critical review of the distribution of stratigraphic units and their lithologic aspects, the following important points emerge:

(i) Gradual decrease in the thickness of the Lower Tal Formation from northwest to southeast till it becomes almost negligible, where the Upper Tal quartzites rest directly over the Krol Formation (near Mathiangaon region on the north limb and Kukhai on the south limb) and then again the Lower Tal rocks are developed though in reduced thickness.




Text Fig. 2

G.S.I. NR. D.O. No. 6274-67-10.

A submarine high (positive) trending roughly along NNE-SSW direction, is postulated in the Kukhai-Mathiangaon region, with basin deepning on either side, Text Fig. 2.

(ii) The chert member, too, thins and finally pinches off against the above mentioned Khukhai-Mathiongaon positive. Maldeota, Jalikhal and Nagani blocks are the only areas, where there is some departure in thickness of chert unit from the regional trends.

(iii) The lithofacies variation in the chert member indicates reciprocal relationship in the thickness of chert unit and phosphate unit. The area bounded by Kimoi-Midlands and Paritibba-Masrana represents the zone of maximum facies change in the chert member and also the multiplicity of phosphate zones in the phosphate unit. This is the tectonic hinge of the basin. North of this hinge phosphate unit is not developed and only thin, horizontally impersistent bands of variegated lenticular phosphate rock bands are seen. South of this hinge, better phosphate rock zones are developed.

(iv) There is gradual increase in the thickness of each member towards North and Northeast (Section in Text Fig. 1). From the foregoing and also from the study of the Text Fig. 2, it is clear that:

(a) Khukui-Mathiangaon region was the highest area in the configuration of the basin bottom, which was sloping gently both to its northwest and southeast. This slope steepens north of Masrana-Paritibba line.

(b) Considering the top of the chert member as a datum plane, its bottom would give the topography of the top of Krol formation, which formed the basement for Tal sedimentation. There appear to be a few undulations in the ocean bottom, which accommodated thicker sections of chert member than its surroundings, the notable among them being Maldeota, Jalikhal, Nagani depression.

(c) Phosphate rock is developed in comparatively shallower region than shale and chert. This is supported by the fact that better grade phosphate unit is developed to the south of the hinge zone and also on the flanks of small undulations. Extending the argument, the vertical sequence from chert shale to phosphate rock, is interpreted as the product of deposition on a rising bottom and the sequence of phosphate rock to shale chert as a product of deposition on a sinking bottom. The former corresponds possibly to the regressive and the latter to the transgressive phases of the sea. In the direction of depression, the beds of phosphate rock split up and are impoverished because of the addition of the argillaceous and siliceous components.

*Condition and Mode Of Formation Of Phosphate Rock.* The common association of phosphate rock with pyrite, other minor elements as uranium and vanadium and organic matter suggests a reducing environment possibly due to restricted circulation in a sheltered sea floor depression or stilled basin (*e. g.* inland sea, gulf or embayment), where chemogenic biogenic processes dominated the sedimentation. The alkalinity presumably fluctuated around 7.8 as phosphate rock indicates pH values less than 7.8 but the associated dolomite and calcite indicate pH values greater than 7.8 The discovery of hystrichosphaeres (Shrivastava and Mehrotra, 1970) and algal limestone (Raha, 1968) within the phosphate unit of the chert member indicate shallow marine conditions, generally around outer neritic zone with depth varying between 30 m to 200 m, where dissolved phosphate content of the muds are highest (Bushinski, 1969).

The phosphate rock is formed by the biochemical process. The soluble phosphate in the mud, derived partly from the decay of phytoplanktons and algae, and partly from the river and sea water, reacts with the precipitating calcium carbonate giving rise to the insoluble calcium phosphate, which after concentration during diagenesis, consolidates as beds of phosphate rock.

The absence of phosphate rocks in Mathiangaon-Khukui positive element, is due to the interruption of the process of phosphate formation, as the area might have been above the zone of restricted circulation of water, thereby rendering the region ineffective as a site of concentration of the soluble phosphates.

*History of Sedimentation.* The later part of Krol sedimentation represented by a thick sequence of dolomitic limestone with occasional algal limestone suggests comparatively shallow marine quiet sedimentation, characteristic of a period of great crustal stability. The absence of an orthoquartzite association with these dolomites and dolomitic limestone, probably indicates that these carbonate rocks have been formed *in situ* and not reworked and that the accompanying positive land mass must be quite low-lying with chemical precipitation dominating the sedimentation. The topmost beds of the Krol Formation (in Mussoorie Syncline) being more argillaceous, indicates gradual influx of the fine terrigenous material suggesting uplift and erosion in the source area. Pre-Tal erosion of Krol Formation in eastern part of the Gharwal Syncline might also have contributed to the fine detritus (Ghosh and Srivatava 1961). However, in the central part of original Tal basin (part of Mussoorie Syncline), there was a period of submarine diastem and and even continued sedimentation (represented by the interlayered argillaceous limestone-phosphate rock/chert sequence). Thus, the possibility that argillaceous limestone and shale occurring at the top of the Krol Formation, in parts of Mussoorie Syncline, may represent the period of erosion in the Garhwal area, cannot be ruled out.

At the beginning of the Tal sedimentation, the tectonic frame work consisted of a stable and mature land mass all around the basin with restricted circulation of water, and flat, slightly rolling basin floor topography. Mildly tectonic hinge was, however, present along Masrana Pari Tibba line, north of which both rate of subsidence and thickness of the chert-member has increased.

History of Tal sedimentation indicates a cycle of deposition by alternate marine transgression regressions. The early Tal sea, during deposition of chert member, was transgressive over the postulated Khukui-Mathiangaon positive resulting in the accumulation of chert, shale, phosphate rock sequence with time planes gradually moving towards the positive element, i. e., the beds nearer to the positive area are younger to the similar beds away from it. The top of the chert member delimits the maximum area of restricted circulation of the water, during the peak of the transgressive phase of the sea. During this time itself, there are at least three cycles of basin floor oscillations as evidenced by three reversals in the vertical sequence, in the upper part of the chert member, from phosphate rock to chert and back to phosphate rock. The occurrence of slump structures, variegated lenticular beds of phosphate rock in Masrana-Kimoi and possibly also Maldeota, support the above contention.

Regression started with the influx of the sediments in the basin, culminating the phase of essentially chemical precipitation, giving an assemblage of black micaceous shales, calcareous and silty shales and siltstone, which consolidated as Argillaceous member. This is followed by thick accumulation of banded siltstones and subgraywackes (turbidites) of the Arenaceous member. Finally the siliceous limestone or calcarenite and associated sandstones, etc. of Calcareous member are deposited probably as shallow water to coastal plain sediments. The above assemblage indicates progressive increase in the tectonic activity in the source area and rapid filling of the basin of depositon. The presence of few small clastic grains of plagioclases in the subgraywackes suggest a possible metamorphic or basic rock provenance of the sediments.

After the deposition of the Lower Tal rocks, there appears to have been a shallowing of the basin, resulting probably in emergence of the Kukhai-Mathiangaon region, which was subjected to erosion also for sometime. This gets support from the occurrence of the conglomerate zone and also the mud crack and rain drop impressions at the base of the Upper Tal quartzites. Then followed the accumulation of shallow marine deposits, which on consolidation yielded Upper Tal Quartzite. The presence of arkosic quartzites (with microcline grains) suggests a granitic terrain being exposed to the erosional agencies.

Post-Tal marine transgression resulted in the deposition of Subathu Formation (Nummulitics).

*Extent of Tal Basin.* It would be beyond the scope of this paper to discuss in detail the extent of the original Tal basin, nevertheless it would be worthwhile to summarise the author's veiws on the subject ( Ravi Shanker, 1970 )*.

The lateral increase in thickness of chert member towards the north-west and also the development of the deeper facies in that direction, suggest that the original Tal basin was not confined to the present limits of the Mussoorie Syncline. Similar studies of the chert member when extended to the Nigali Dhar and Korgai synclines in the Sirmur district, Himachal Pradesh indicate that the thicker and the deeper facies are developed to the southeast.

The above observations suggest that the two areas probably represent the opposite

*Detailed paper discussing the subject is under preparation and would follow soon.

flanks of the same basin with the deepest portion somewhere in the middle, traces of which are not found now, due to the subsequent deeper erosion by the Yamuna and Tons rivers. Further to the southeast of the Mussoorie syncline, the original Tal basin appears to be extending at least upto the eastern portion of the Garhwal syncline in the Pauri district of U. P., whereas its western and possibly also the central portion was exposed to the weathering agencies.

## SUMMARY

(1) Tal formation has been divided into two units (viz., the Lower and Upper Tal formations) separated by a disconformity. The lower Tal formation is further divided into four mappable units (*viz.*, the Chert, Argillaceous, Arenaceous and Calcareous members) on the basis of gross lithological characters. Recently demarcated phosphate beds generally occur in the upper part of the Chert member. Similarly, the Upper Tal formation is divided into two mappable units (*viz.*, Quartzite Member and Limestone Member).

(2) The nature of the Krol-Tal contact is mainly governed by the location of the area in the original depositional basin from complete transition through submarine diastem to erosional unconformity.

(3) Lateral and vertical relationship of various litho-units, particularly those associated with the phosphate beds, brings out clearly the undulating topography of the ocean floor of the Tal sea, which was deepening towards northwest

(4) Phosphate rock is formed by biochemical process.

(5) Restricted circulation, relatively shallow depth of water, and uneven basin topography appear to be the main controlling factors in the formation of phosphate rock.

(6) History of Tal sedimentation indicates deposition by alternate marine transgression and regression.

(7) The original Tal basin extended much beyond the present limit of the Mussoorie syncline. The Nigali Dhar, Korgai and part of Garhwal Syncline are also the remnants of the same basin.

## ACKNOWLEDGEMENTS

Thanks are due to Shri S.C. Chakravarty, Director, Mineral Exploration Division, Northern Region, G.S.I., for stimulating and thought provoking discussions, and critical review of the manuscript.

## REFERENCES

Auden, J.B., 1934. Geology of Krol *Belt. Rec. GSI* 67 (4).

Bushinski, G., 1969. Old Phosphorites of Asia and their Genesis (*Translated from Russian under I.P.S.T., Jerusalem*).

Ghose, A., 1968. A Report on the Stratigraphy, Structure and Tectonics of a part of the Mussoorie syncline. (*Unpublished G.S.I. Report*).

Ghosh, A.K. and Srivastava, S.K., 1961. Microfloristic evidence on the age of the Krol beds and associated formations. *Proc. Nat. Inst. of Sci.* **28**—A, 5.

Raha, P.K., *et al.*, 1968, Progress Report on the Phosphorite Investigation in the Chamasari area, District Dehradun, for field season 1966—67, (*Unpublished G.S.I. Report*).

Ravi Shanker, 1967, Geology of the part of Mussoorie syncline, districts Dehradun and Tehri, U.P. (*Unpublished G.S.I. report*).

IDEM, 1970, Stratigraphic Analysis of the Chert Member Lower Tal formation in Dehradun and Tehri districts, U.P. (*Unpublished G.S.I. Report*).

RUPKE, I. *et at.*, 1968, Reconnaisance Geological map of Kumaon Himalayas. (*Unpublished I.P.I. Report*).

SHRIVASTAVA, R.N., 1963a. Fossil Lamellibranch from the Lower Tal shales in Mussoorie-Dehradun area, U.P. Sym. on Himalayan Geology, G.S.I. (*abstracts*). 41.

IDEM, 1963b. Fossil Fauna of the Lower Tal shales of Mussoorie syncline, Tehri Garhwal district, U.P. *ibid* 41.

SHRIVASTAVA, R.N. AND MEHROTRA P.C. 1970, Personal Communications on recent Palynological work in shales of the phosphate unit, chert member.

TIWARI, B.S. AND GUPTA, R., 1967. Foraminifera from Nummulitic beds of Nilkanth and Organic remains from Tal Limestone, Garhwal Himalayas. *Pub. of Centre of Advance Study in Geology*, No.3: 53—39.